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(54) Multi-frequency transducer elements

(57) A sonar transducer array comprises a number of transducer elements 3, 4 some of which are capable of operating at two different frequencies. The dual-frequency transducer elements 4 have a piezo-electric oscillator 71, 72 sandwiched between an aluminium alloy forward resonator 73 and a steel rear resonator 74. The forward resonator 73 is of frusto-conical shape with an enlarged forward end from which the majority of acoustic energy is propagated. The rear resonator 74 is of trapezoidal shape. Although the resonators 73 and 74 are of different shapes, they are arranged to have substantially identical fundamental resonant frequencies and a substantially identical higher harmonic resonant frequency so that the dual-frequency elements 4 are capable of operating both at the frequency of the other elements 3 and at a higher frequency such as to produce a more directional beam.

Fig. 2.

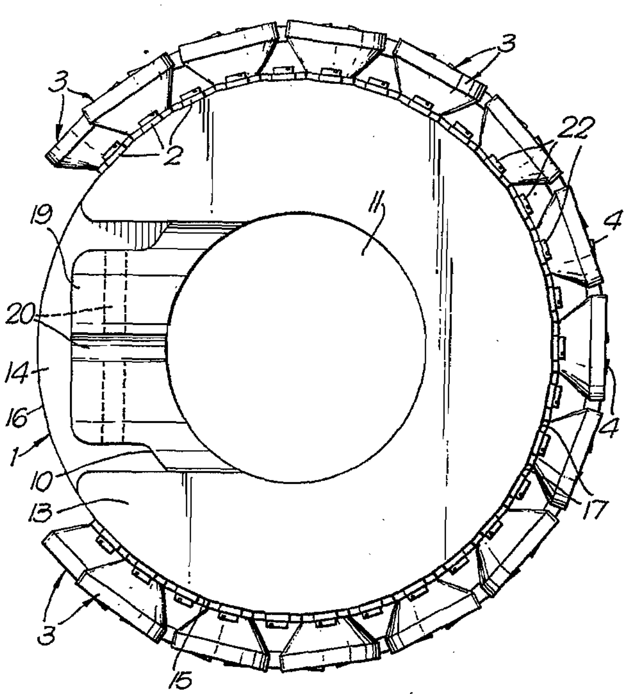
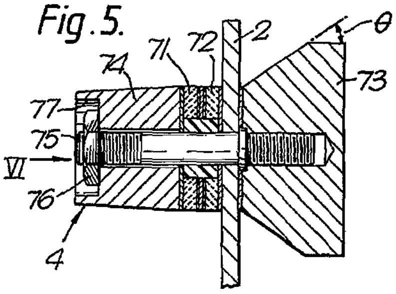


Fig. 5.



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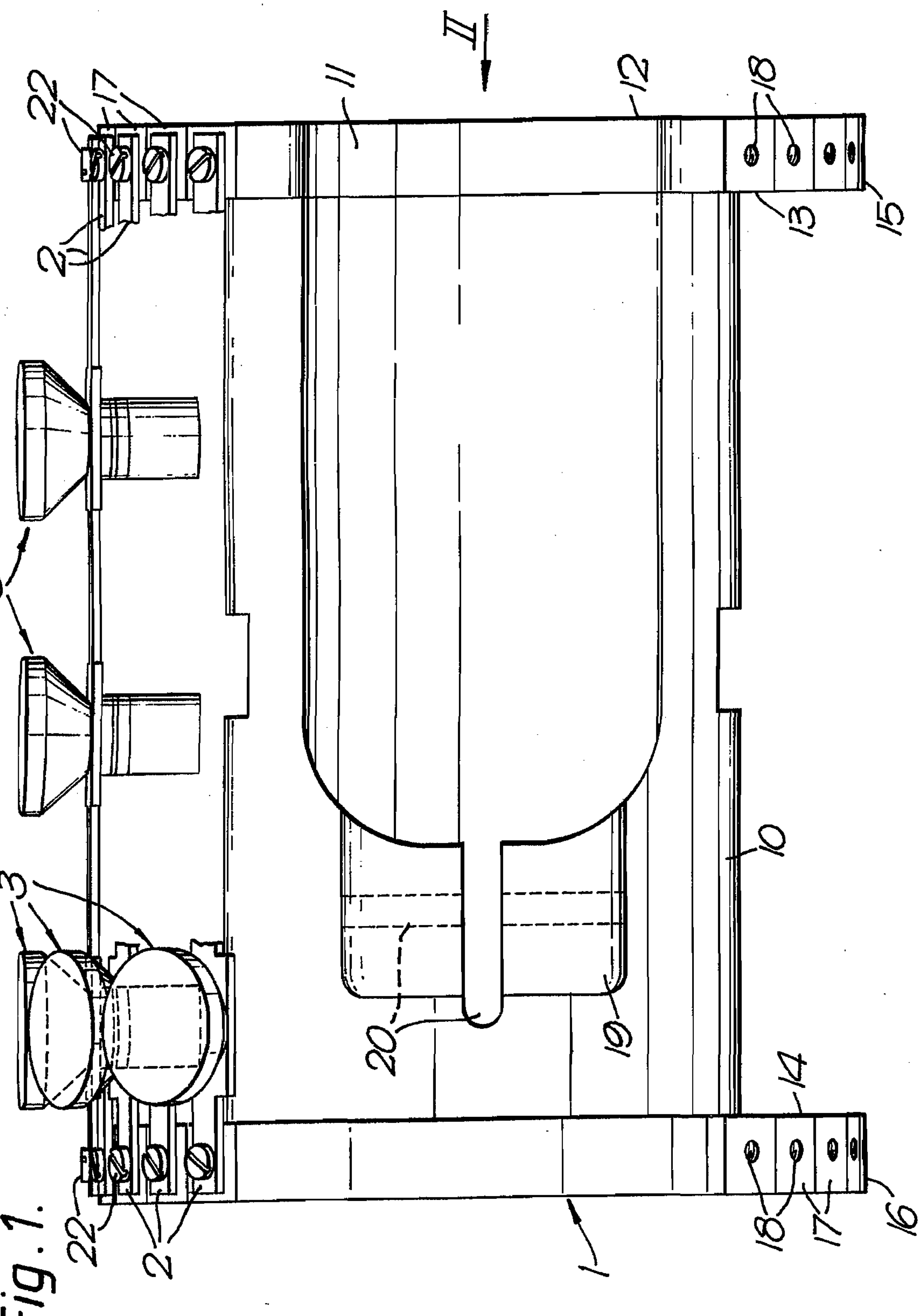

Fig. 1.

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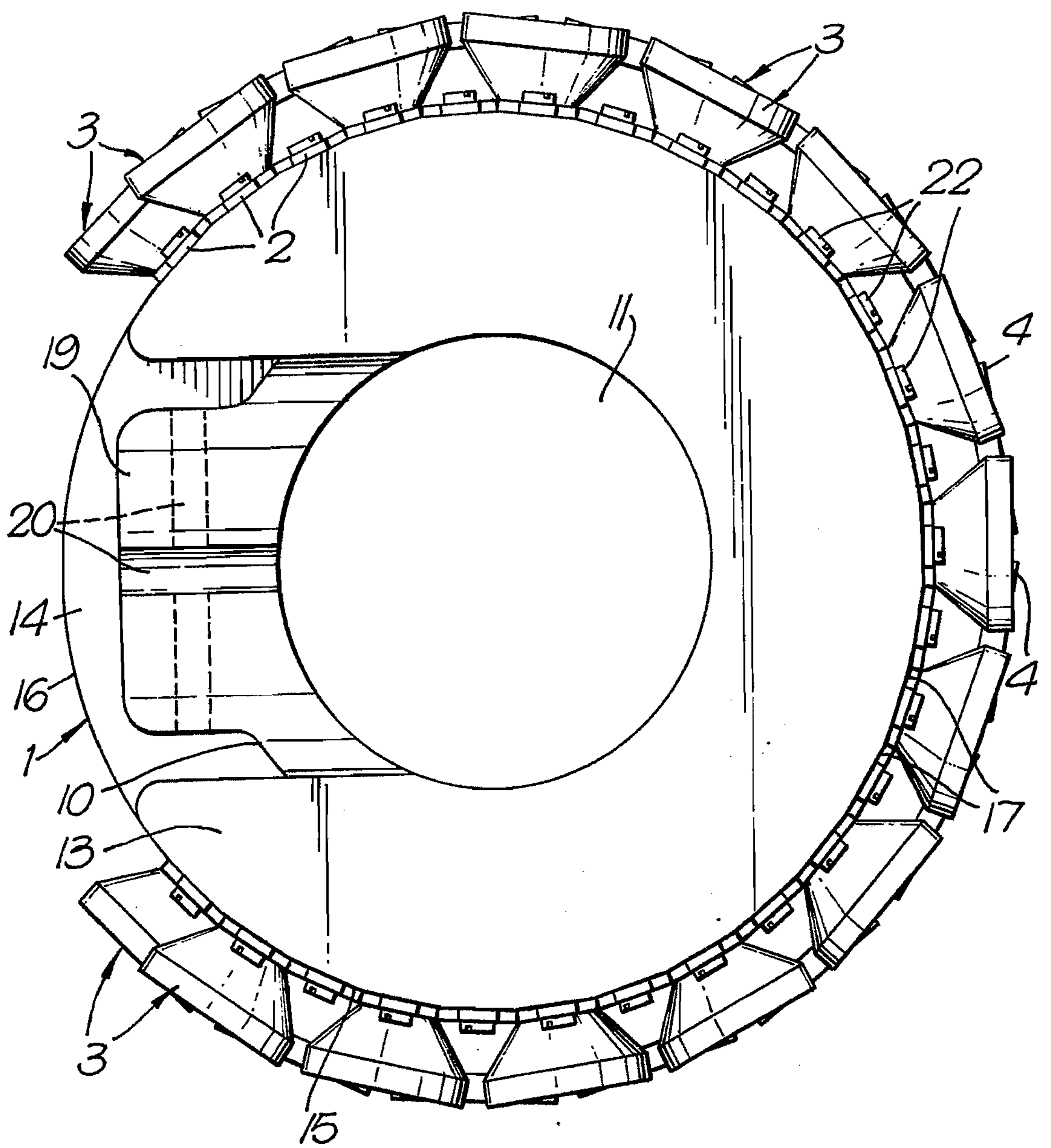
Fig. 2.



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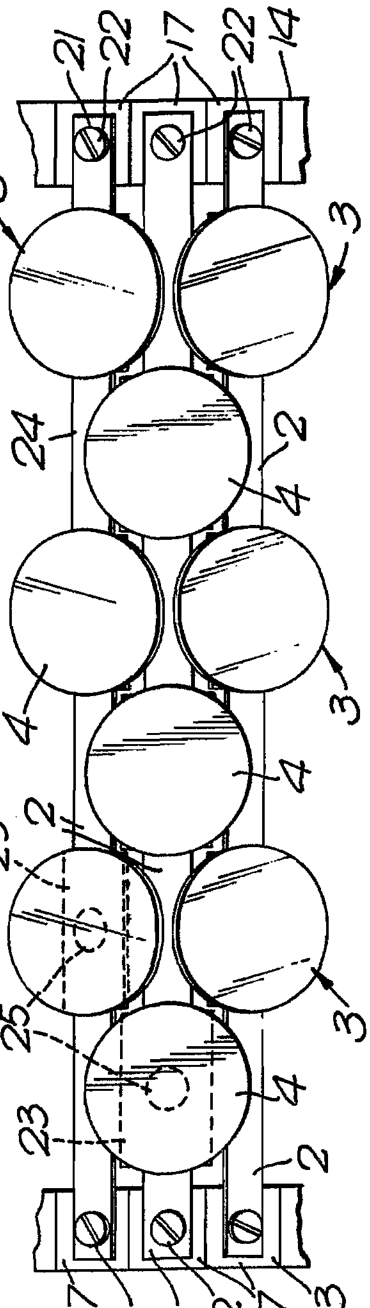

Fig. 3.

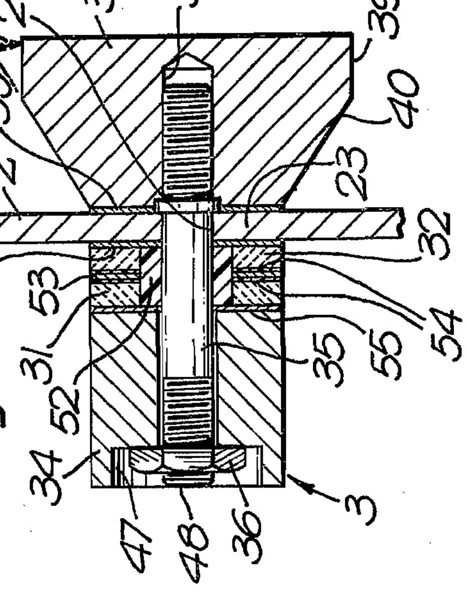

Fig. 4.

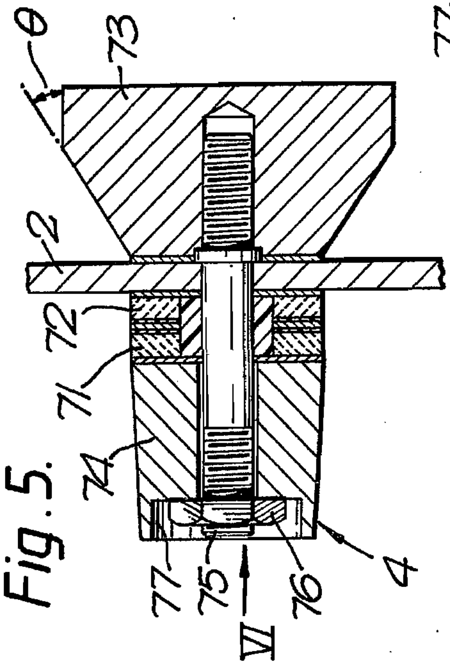

Fig. 5.

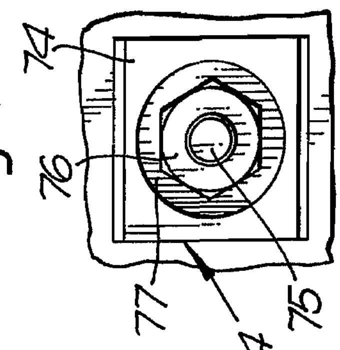

Fig. 6.

SPECIFICATION

Electro-acoustic transducers

This invention relates to electro-acoustic tranducer elements and arrays including such elements. The invention is more especially concerned with transducer elements for use in sonar apparatus.

In some sonar applications, it is useful to be able to generate acoustic energy at two different frequencies, the lower frequency being used in normal operation and the higher frequency being used when a more selective, directional beam of radiation is required for a detailed examination of a region, such as, for example, a shoal of fish, or a selected area of sea-bed. Conventionally, apparatus capable of operating at two frequencies have had two sets of transducer elements, one set being dedicated to operation at one frequency and the other set being dedicated to operation at a different, higher frequency. The two sets might, for example, be mounted as an array one above the other within a fluid-tight housing that is substantially transparent to acoustic energy, the housing being mounted on the hull of a ship, beneath the waterline.

The above conventional arrangement has the disadvantage that, because two separate sets of transducer elements are required, the array is larger, heavier and more complex than assemblies that operate only at one frequency.

It is an object of the present invention to provide a sonar transducer element and an array including such an element that can be used substantially to alleviate the above-mentioned disadvantages.

According to one aspect of the present invention there is provided an electro-acoustic sonar transducer element including oscillator means that is arranged to oscillate in response to an alternating electric signal supplied to said oscillator means, first resonator means coupled with said oscillator means, said first resonator means having a first fundamental resonant frequency and a plurality of harmonic resonant frequencies, and second resonator means coupled with said oscillator means, said second resonator means having a second fundamental resonant frequency and a plurality of harmonic resonant frequencies, the said second resonator means being arranged such that at least two of the resonant frequencies of said second resonator means are substantially identical to at least two of the resonant frequencies of said first resonator means so that said element can thereby be operated at said two or more frequencies.

The first fundamental resonant frequency and the second fundamental resonant frequency may be substantially identical. The first and second resonator means may be of different materials and different shapes. In this respect, one of the resonator means may have a portion at least that is of frusto-conical shape and the other resonator means may have a portion at least that is of trapezoidal shape, one resonator means having a greater effective surface area than the other of said resonator means such that a greater proportion of acoustic energy is propagated in one direction than in the opposite direction. The first and second resonator means may be mounted on opposite sides of said oscillator means.

According to another aspect of the present invention there is provided an electro-acoustic sonar transducer array comprising a plurality of sonar transducer elements arranged to propagate acoustic energy outwardly of said array, wherein said elements are resonant at a first frequency, and wherein some at least of said elements are resonant also at a second frequency higher than said first frequency.

According to a further aspect of the present invention there is provided an electro-acoustic sonar system comprising an electro-acoustic sonar transducer element and electrical supply means for driving said transducer element, wherein said transducer includes: oscillator means; first resonator means coupled with said oscillator means, said first resonator means having a first fundamental resonant frequency and a plurality of harmonic resonant frequencies; and second resonator means coupled with said oscillator means, said second resonator means having a second fundamental resonant frequency and a plurality of harmonic resonant frequencies, wherein at least two of the resonant frequencies of said second resonator means are substantially identical to at least two of the resonant frequencies of said first resonator means, and wherein said electrical supply means is arranged to supply a drive signal to said transducer element at either of said two resonant frequencies such that the system can propagate acoustic energy at either frequency.

A sonar transducer element and a transducer array, in accordance with the present invention, will now be described, by way of example, with reference to the accompanying drawings, in which:

Figure 1 is a partly cut-away elevation side view of the array;

Figure 2 is a view from the right hand end of the array of Figure 1 along the arrow II;

Figure 3 shows a part of the array of Figure 1;

Figure 4 is a cross-sectional elevation to an increased scale of one element of the array of Figure 1;

Figure 5 is a cross-sectional elevation to an increased scale of another element of the array of Figure 1; and

Figure 6 is a view from the rear of the element of Figure 5 along the arrow VI.

With reference to Figures 1 and 2, the sonar transducer array comprises a central mounting drum 1 around which are mounted twenty seven mounting bars 2, each carrying three transducer elements. Seventy seven of the elements 3 are arranged for operation at only one frequency, and four of the elements 4 are arranged for operation at both that one frequency and at a higher frequency.

The mounting drum 1 is an aluminium alloy casting with a hollow cylindrical hub 10 that has an open side 11 extending about half way along it from the right-hand end 12. Annular flanges 13 and 14 extend radially from the hub 10 at both ends, the left-hand flange 14 being substantially circular and the right-hand flange 13 being partly cut-away such as to be of

generally U-shape (Figure 2). The outer edges 15 and 16 of both flanges 13 and 14 are formed with a series of twenty seven flats 17 spaced around 280°, each of which has a centrally positioned tapped hole 18. The drum 1 is also provided with a mounting flange 19 that projects radially from the hub 10 intermediate the end flanges 13 and 14. The mounting flange 19 is provided with various bolt holes 20 for use in mounting the drum 1 with, for example, the hull of a ship (not shown).

With reference now also to Figure 3, the mounting bars 2 extend between the two end flanges 13 and 14 parallel to the axis of the drum 1, each bar 2 having a hole 21 at both ends for receiving bolts 22 that are screwed into the holes 18 in the flanges. The bars 2 are of 2 mm thick aluminium alloy and may be simply formed by stamping from a flat sheet of material. The bars 2 are of generally rectangular shape being provided with three plate portions 23 that are separated from one another by waisted portions 24 of reduced width. The plate portions 23 are located closer to one end of the bar 2 than the other end, the bars 2 being mounted on the drum 1 in an alternate, reversed fashion such that the plate portions 23 of one bar are aligned with the waisted portions 24 of the adjacent bars. The plate portions 23 are flat and free from surface imperfections and are formed with centrally-located apertures 25 for use in mounting the transducer elements 3 and 4.

All of the transducer elements are of the single-frequency kind except for a group of four elements 4 which are of the dual-frequency kind and which are arranged together on three adjacent bars 2. The dual-frequency elements 4 are arranged in a lozenge configuration, two elements being located one another on one bar 2, and the other two elements being mounted intermediate the first two elements, on respective bars on either side.

With reference now to Figure 4, the single-frequency transducer elements 3 are of the electro-acoustic form having two barium titanate, piezo-electric ceramic crystals 31 and 32 sandwiched between head and tail tuned resonators 33 and 34. Each transducer element 3 is secured on its mounting bar 2 by means of a threaded stud 35 and nut 36. The stud 35 extends axially through the tail resonator 34, the crystals 31 and 32, and the aperture 25 in the bar 2, and screws into a tapped hole 37 in the head resonator 33. The head resonator 33 is 12.7 mm long and is of an aluminium alloy having a cylindrical forward section 39 of 24.69 mm diameter that tapers rearwardly at an angle θ of 32°08′ to a reduced diameter (of 13.80 mm), thereby forming a frusto-conical section 40. The head resonator 33 is held tightly with the plate portion 23 of the bar 2, being separated from it by means of a monel gauze shim 50. A similar shim 51 is sandwiched between the other side of the plate portion 23 and the front surface of the forward crystal 32.

The crystals 31 and 32 are both of annular form having an outer diameter of 13.8 mm, a bore 7.00 mm in diameter, and being 2.32 mm thick. The crystals 31 and 32 are arranged to oscillate axially such that radiation is propagated along the length of each element 3 and radially outwards of the mounting drum 1. An electrically-insulative sleeve 52 is fitted in the bore of the two crystals to embrace the stud. The two crystals 31 and 32 are separated from one another by a brass shim 53, which serves as an electrode, and two monel gauze shims 54 positioned on opposite sides of the brass shim. Another monel gauze shim 55 separates the rear crystal 31 from the tail resonator 34.

The tail resonator 34 comprises a cylindrical block of stainless steel 14.2 mm long and 13.8 mm in diameter provided with a 4 mm deep circular recess 47 in its rear face 48 which receives the nut 36. Before assembling the elements 3 with the bars 2, all contacting surfaces of the components of the transducer element are coated with an epoxy adhesive which sets hard to produce secure joints.

The greater effective surface area provided by the flat front face of the head resonator compared with the rear face of the tail resonator gives a greater propagation of energy in the forward, outward direction.

The shape, size and material of the head resonator 33 and the tail resonator 34 are chosen so that both will resonate at the same fundamental frequency, namely 55kHz. The harmonic frequencies of the head and tail resonators 33 and 34 are not, in general, equal.

The position of the mounting bar 2 along the length of the transducer element 3 is such that the bar is at a node point in the vibration of the element so as thereby to ensure that as little vibration as possible is transmitted to the bar. The waisted portions 24 of the bar 2 further ensure that mutual coupling between adjacent transducer elements 3 on the same bar is maintained at a minimum.

A dual-frequency transducer element 4 is shown in Figures 5 and 6 and, in many respects, is identical to the single-frequency transducer element 3 of Figure 4. The dual-frequency transducer element has two crystals 71 and 72, identical to those of the single-frequency transducer element 3, sandwiched between head and tail tuned resonators 73 and 74. The dual-frequency transducer elements 4 are secured to the bars 2 in the same way as the single-frequency transducer elements 3, and the head resonator 73 is of the same material, shape and size as the head resonator 33 of the single-frequency transducer element. The tail resonator 74, is also of the same material as the single-frequency tail resonator 34, but is of a different shape. The dual-frequency tail resonator 74 is of trapezoidal shape having a square forward end that is 13.80 mm by 13.80 mm and tapering rearwardly to a rectangular rear end that is 13.80 mm by 11.55 mm. The tail resonator is 12.75 mm long and has a 2.75 mm deep circular recess 77 in its rear face.

The tail resonator 74 of the dual-frequency transducer has a fundamental resonant frequency of 55kHz and a higher harmonic resonant frequency of 130kHz which frequencies coincide respectively with the fundamental resonant frequency and the higher resonant frequency of the head resonator 73.

The crystals of both the single-frequency transducer elements 3 and the dual-frequency elements 4 are supplied with an alternating electrical signal of

55kHz and the echo returns received by the same elements are processed and displayed in the usual manner. When it is desired to make a more detailed examination of a particular region, the source of 55kHz signal is disconnected from the array and a 130kHz signal is instead supplied to only the dual-frequency elements 4, thereby producing a more directional beam of acoustic energy.

By using some of the same elements to ptoduce and receive both the low and high frequency signals an overall saving can be made on the size, weight and complexity of the transducer array.

CLAIMS

1. An electro-acoustic sonar transducer element including oscillator means that is arranged to oscillate in response to an alternating electric signal supplied to said oscillator means, first resonator means coupled with said oscillator means, said first resonator means having a first fundamental resonant frequency and a plurality of harmonic resonant frequencies, and second resonator means coupled with said oscillator means, said second resonator means having a second fundamental resonant frequency and a plurality of harmonic resonant frequencies, the said second resonator means being arranged such that at least two of the resonant frequencies of said second resonator means are substantially identical to at least two of the resonant frequencies of said first resonator means so that said element can thereby be operated at said two or more frequencies.

2. A transducer element according to Claim 1, wherein said first fundamental resonant frequency and said second fundamental resonant frequency are substantially identical.

3. A transducer element according to Claim 1 or 2, wherein said first and second resonator means are of different shapes.

4. A transducer element according to any one of the preceding claims, wherein said first and second resonator means are of different materials.

5. A transducer element according to any one of the preceding claims, wherein the effective surface area of one of said resonator means is greater than that of the other of said resonator means such that a greater proportion of acoustic energy is propagated in one direction than in the opposite direction.

6. A transducer element according to any one of the preceding claims, wherein one of said resonator means has a portion at least that is of frusto-conical shape.

7. A transducer element according to any one of the preceding claims, wherein one of said resonator means has a portion at least that is of trapezoidal shape.

8. A transducer element according to any one of the preceding claims, wherein said first and second resonator means are mounted on opposite sides of said oscillator means.

9. A transducer element according to any one of the preceding claims, wherein said oscillator means includes a piezo-electric oscillator.

10. A transducer element according to any one of the preceding claims, wherein said transducer is supported intermediate said oscillator means and one or other of said resonator means.

11. A sonar transducer array including a plurality of transducer elements arranged to propagate acoustic energy outwardly of said array, wherein at least one of said elements is an element according to any one of the preceding claims.

12. An electro-acoustic sonar transducer array comprising a plurality of sonar transducer elements arranged to propagate acoustic energy outwardly of said array, wherein said elements are resonant at a first frequency, and wherein some at least of said elements are resonant also at a second frequency higher than said first frequency.

13. An electro-acoustic sonar system comprising an electro-acoustic sonar transducer element and electrical supply means for driving said transducer element, wherein said transducer includes: oscillator means; first resonator means coupled with said oscillator means, said first resonator means having a first fundamental resonant frequency and a plurality of harmonic resonant frequencies; and second resonator means coupled with said oscillator means, said second resonator means having a second fundamental resonant frequency and a plurality of harmonic resonant frequencies, wherein at least two of the resonant frequencies of said second resonator means are substantially identical to at least two of the resonatn frequencies of said first resonator means, and wherein said electrical supply means is arranged to supply a drive signal to said transducer element at either of said two resonant frequencies such that the system can propagate acoustic energy at either frequency.

14. An electro-acoustic sonar transducer element substantially as hereinbefore described with reference to Figures 5 and 6 of the accompanying drawings.

15. An electro-acoustic sonar transducer array substantially as hereinbefore described with reference to Figures 1 to 6 of the accompanying drawings.

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